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First
Progress Report
on

Motorboat Fire Extinguisher Evaluation

by

M. Shoub and T. G. Lee

Fire Protection Section
Building Technology Division

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MOTORBOAT FIRE EXTINGUISHER EVALUATION

ABSTRACT

The National Bureau of Standards has reviewed a proposed evaluation procedure for fire extinguishers intended for use on motorboats. Preliminary tests have been performed on a group of fires simulating those which might occur during motorboat fires. These fires have been modified to present a wide range of extinguishment problems while maintaining nearly constant fuel consumption rates. A proposal is made for continuation of the investigation with the use of fifteen different fire extinguishers and ten test fires.

1. INTRODUCTION

For some time there has been doubt as to the value of tests involving the use of spill type gasoline fires for evaluation of hand portable fire extinguishers submitted to the Coast Guard for approval for use on motorboats. The question was raised as to whether this type of fire presented an extinguishment problem comparable to those encountered in actual motorboat fires. It was further suggested that this type of fire provided an easy extinguishment problem to certain types of extinguishers while at the same time presenting a difficult extinguishment problem for other types. In an attempt to provide some answer to this question the Coast Guard undertook to design and construct a series of enclosures within which fires could be built. These enclosures were designed to more closely simulate the geometrical configuration of a motorboat engine compartment, galley, and bilge within each of which fires were considered as possible. These models, together with spill and tub types as used by both the National Bureau of Standards and Underwriters' Laboratories, were used in a series of tests at Curtis Bay, Maryland, in 1951. The results of these tests were inconclusive but did indicate a need for a much larger investigation of the problem and suggested certain modifications as desirable in the experimental equipment.

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1. INTRODUCTION

For some time there has been doubt as to the value of tests involving the use of spill type gasoline fires for evaluation of hand portable fire extinguishers submitted to the Coast Guard for approval for use on motorboats. The question was raised as to whether this type of fire presented an extinguishment problem comparable to those encountered in actual motorboat fires. It was further suggested that this type of fire provided an easy extinguishment problem for certain types of extinguishers while at the same time presenting a difficult extinguishment problem for other types. In an attempt to provide some answer to this question the Coast Guard undertook to design and construct a series of enclosures within which fires could be built. These enclosures were designed to more closely simulate the geometrical configuration of a motorboat engine compartment, galley, and bilge within each of which fires were considered as possible. These models, together with spill and tub types as used by both the National Bureau of Standards and Underwriters' Laboratories, were used in a series of tests at Curtis Bay, Maryland, in 1951. The results of these tests were inconclusive but did indicate a need for a much larger investigation of the problem and suggested certain modifications as desirable in the experimental equipment.

In January 1954 the National Bureau of Standards was requested to undertake to carry on the investigation which had been started. A project was therefore initiated for study of this problem. No extensive work was done on the problem until August and September of this year.

This report presents a brief description of the work accomplished since that time. A definite experimental program is proposed for the purpose of obtaining the necessary information.

2. EXAMINATION OF AND TESTS WITH COAST GUARD EQUIPMENT

An examination of the Coast Guard setups, both from plans submitted and actual equipment transferred to the Bureau showed that in general the experimental program and method of attack were sound. That the size of the fires was arbitrarily fixed, is considered no detriment as no other course appears practicable in view of the almost infinite variety of combinations of conditions that may occur in actual service.

The fires used in the Coast Guard tests fall generally into three categories: (1) fires similar to those used by the Bureau and Underwriters' Laboratories, Inc. to evaluate extinguishers bearing the B-2 U.L. rating, i.e. devices suitable for small flammable liquid fires; (2) those in a structure simulating an engine compartment in a small motorcarft; and (3) fires of special character possibly met in practice and not encountered in the other two categories.

Preliminary tests were made using the Coast Guard equipment as supplied, with emphasis on the motor compartment fires. Considerable variability of performance was noted both from test to test and also among the several types of extinguishers. It was observed that the equipment was not substantial enough to closely maintain the same extinguishing problem in successive tests. Consequently, the tests were discontinued until a heavier engine compartment and simulated block could be constructed.

As the fire tests would necessarily be conducted outdoors, tests were performed with the objective of determining what effect, if any, atmospheric conditions

would have on the extinguishing characteristics of the different types of extinguishers. To this end, tests were made with sample carbon dioxide, vaporizing liquid and dry chemical extinguishers on gasoline spill and tub fires, similar to NRL and Underwriters' Laboratories standard fires, under a wide range of ambient conditions. Similar experiments were also performed in a number of tests of engine compartment fires, both with the equipment as received and also as subsequently modified at the Bureau.

In the tests made with the heavier engine compartment, the variability among the different types of extinguishers was confirmed. It was found that not only did extinguishers vary by type on a single fire, but also extinguishers of a given type showed considerable variation in performance as the configuration of the engine compartment was changed.

During this initial experimental study, a review was made of extinguishers, both of Coast Guard approved models and those of a type considered suitable for approval, for the purpose of selecting those which should be included in the experimental program. The list of 15 devices finally selected and later accepted by the Coast Guard is included as Appendix A of this report.

3. FUEL CONSUMPTION MEASUREMENTS

In performing the tests with the equipment as supplied and also as initially modified, it was noted that the rate of fuel consumption determined from the total burning time as observed during complete consumption of the fuel, varied considerably among the several types of test setups. It was decided to determine more accurately the rate of fuel expenditure. The fuel, Skellysolve C*, used for these studies comprised a mixture of heptanes, the principal fraction of gasoline. This fuel, unlike gasoline, has a narrow distillation range. This appeared desirable for the purpose of achieving a more uniform time-rate of combustion.

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*Skellysolve C an industrial solvent is manufactured by the Skelly Oil Company, Kansas City, Missouri, and is reported to comprise a mixture of heptanes having a distillation range of 186°F-212°F.

In the 4-ft by 4-ft test fire, it was found that the average rate of consumption varied from 15 to 20 milliliters per second. This type of fire, conducted outdoors appeared particularly susceptible to atmospheric change. The modified 2-ft tub, on the other hand, had a consistent consumption rate of 11.4 ml/sec. Values for the cotton waste fires could not be readily determined as the large amount of Class A material effectively masked the burning of the Class B fuel. These three fires, with their varying rates of fuel consumption, are similar to those that have been used by the Underwriters' Laboratories to evaluate small hand portable extinguishing devices.

In tests of the bilge space and engine compartment, with and without the simulated water block, the fuel consumption rates ranged from 9 to 17 ml/sec for the different configurations. For these tests, a wood floor grating was used, which although partially consumed in the fire, did not prevent close determination of the moment of fuel exhaustion. The pierced dripping bucket fire had a consumption rate of approximately 6 ml/sec which value could, of course, be readily changed by altering the size of the hole. Measurements were omitted on the galley stove type fire as the character of the proposed test fire discouraged attempts to measure the rate of fuel consumption.

As noted, the preliminary studies have shown that the effectiveness of an extinguisher of a certain type, varied considerably with the design of the test fire. If in the proposed studies the rate of fuel consumption could be held constant, then the extinguisher capability would become largely a function of the geometry of the fire with the special problem that each configuration presents. As these extinguishers, of several types, are all intended for the same service, it was considered that use of a uniform consumption rate in the tests specially devised for this investigation would offer an advantageous means of evaluating all of the devices. A value of 13±1 ml/sec was chosen as experiments have shown that in the configurations used this consumption rate gives fires of a size capable of being extinguished in a sufficient number of cases to justify the study. To achieve this uniformity further modifications were made in the experimental fires. In the case of the vertical surface fire, simulating a possible condition with a defective galley stove, the intended fuel is denatured alcohol. For this fire, the fuel flow rate will be adjusted so that the expected heat output, based on the

assumption of complete combustion, will be approximately the same as that of the test fires using Shellsolve C. The proposed test fires are described in Appendix A. A sample data sheet is included (Appendix B) as an indication of the observations to be made during the individual tests.

4. Study of Fuels

An investigation was made of the combustion rates of three hydrocarbon fuels: (1) Standard "regular" gasoline (leaded) supplied on Government Purchase Contract and available at [illegible] until July 1955; (2) Gulf marine gasoline (unleaded), and (3) Shellysolve C, a mixture of heptanes, available indefinitely. Regular gasoline was chosen as the most readily available fuel, marine gasoline as representative of fuels usually recommended for waterboat use, and Shellysolve C as a fuel with a considerably narrower distillation range (150° to 212°F) than that of commercial gasolines, a typical example of which has fractions volatilizing at temperatures of 89° to 409°F.

Visually, there is no appreciable difference in the burning characteristics of regular gasoline and marine fuel. Both ignite with a sudden burst of flame because of the concentration of highly volatile vapors above the liquid surface. The fires then reach a stage of moderate equilibrium which continues until only the heavier fractions of the fuel remain. These burn with a low, dark flame, producing a considerable volume of smoke. After prolonged flickering, the fire goes out leaving a residue of unburned tars. In contrast, Shellysolve C starts burning evenly, quickly comes to a stable condition and maintains a rather constant rate of burning until the fuel is exhausted, at which time the fire goes out suddenly. It develops little smoke during combustion and leaves almost no residue after completion of combustion.

Measurements were also made of the actual evaporation rates and radiant energy output of the three fuels. The fire source was 0.700 lb fuel placed over 2 1/2 in. water in a 4-in. deep pan of 11-in. diameter. The pan was placed on a scale which was read to the nearest 0.005 lb at 15-sec intervals during the entire progress of the

fire. Comparative radiant energy measurements were made with a radiometer and a potentiometer recorder. For each of the three fuels, a fairly constant consumption rate was attained at 30 to 40 seconds after ignition and continued for 2½ to 3 min for the two gasolines and 4 min for the Skellysolve C. Energy outputs reached a constant rate at 1 min but were not appreciably below the constant rate at 30 seconds. The average radiant energy output of the three fuels was nearly the same. The radiant output of Skellysolve C was more uniform and as with the consumption rate, remained constant for a longer period than did that of either of the two gasolines. It is therefore proposed that future evaluation studies be performed with the use of this material as a fuel.

It is possible that criticism could result from use of this special fuel as a substitute for gasoline as commonly used in motorboats. To obviate such criticism it is planned to run a sufficient number of duplicate tests using the two fuel types. This will be done early in the investigation to permit prompt modification of this plan should the experimental results warrant it.

5. SCHEDULE OF TESTS

It can be seen from Appendices 1 and 2 that the program would comprise tests of fifteen extinguishers on ten different fires as a minimum, and as each extinguisher would be tested five times on each fire, the entire program will consist of at least 750 separate fire tests. Five repetitions are employed as this number together with a system of weighting extinguisher performance is considered likely to give sufficient data for a significant statistical analysis of the results.

As weather factors appear likely to influence the outcome of the tests, the following schedule (numbers refer to extinguishers) has been devised to take

account in the analysis of the effect of this variable for each of the ten types of fires.

Run 1			Run 2			Run 3			Run 4			Run 5		
1	8	3	4	5	6	7	8	9	10	11	12	13	14	15
4	11	14	3	8	13	2	10	12	1	5	9	6	7	15
5	7	15	2	10	14	3	4	12	7	8	13	1	2	11
6	9	10	1	12	15	5	11	13	2	7	14	3	4	9
2	12	13	5	7	11	1	6	14	4	9	15	8	10	12

It will be noted that the above schedule has the property that each run is divided into five time periods and that all 15 extinguishers are used in each of the five time periods.

It is planned that the order of the test within the sets of three will be at random, and the rows and columns of the design will be permuted in a random way for the assignment for test on the other fires.

6. PROPOSED EVALUATION PROGRAM

It is considered that the work described above justifies initiation of the large scale evaluation of the fifteen different extinguishers on ten different test fires. It is therefore proposed to initiate this study immediately using the modified test fires and Unleaded Motor Gasoline as the fuel. As mentioned earlier it is proposed to use five duplicate tests of each fire and extinguisher type. Preliminary study of the type data likely to result from this type of investigation indicates that considerable confidence will be achieved in the resulting evaluative of the comparative behavior of the extinguishers.

Appendix A

List of Extinguishers for Motorboat Fire Tests

Vaporizing Liquid:

1-qt CCl_4	Pump Can (liquid)	American-La France
1-qt CCl_4	Pump Can (air)	Pyr-Fyter
1-qt CCl_4	Stored Pressure	Stop-Fire
1-qt $CBrF_3$	Stored Pressure	Stop-Fire
1½-qt CCl_4	Pump Can (liquid)	General Detroit
1½-qt CCl_4	Pump Can (air)	Pyr-Fyter
1½-qt CCl_4	Stored Pressure	Stop-Fire
2-qt CCl_4	Stored Pressure	Pilster or Pyrene

Carbon Dioxide:

2½-lb	Pistol-grip	Kidde
5-lb	Squeeze-grip	Pyr-Fyter
10-lb	Squeeze-grip	Pyr-Fyter

Dry Chemical:

4-lb	Cartridge-type	General Detroit
4-lb	Stored Pressure	Safety-First
5-lb	Stored Pressure	Circle

Foam:

1½-gal	Badger

Fire Test No: 1 (CG-MMT-MBFT-I)

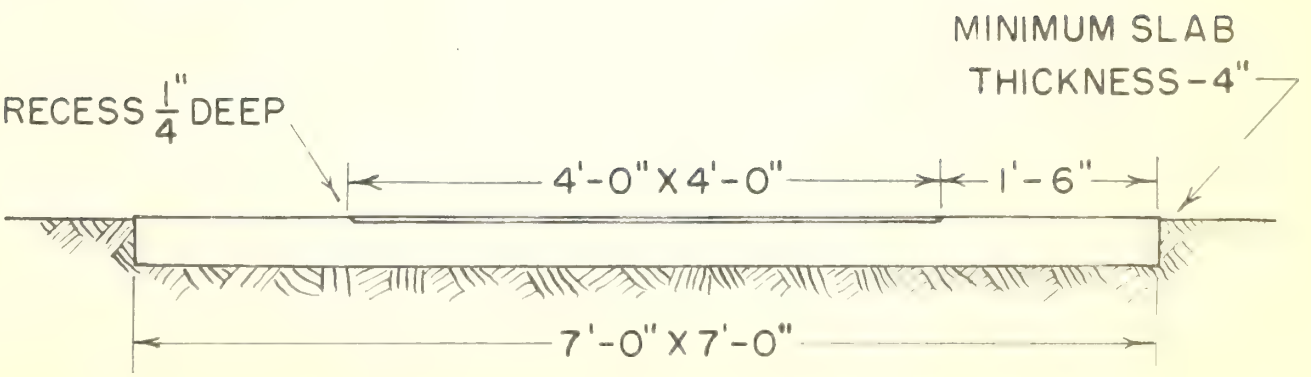
Type of Fire: Gasoline spill

Test Apparatus: Shown in sketch

Fuel: $2\frac{1}{2}$ qt in recessed area

Preburn Time: 5 seconds

Method of Attack: Begin application at windward edge of fire.



Fire Test No: 2 (CG-MMT-MBFT-II)

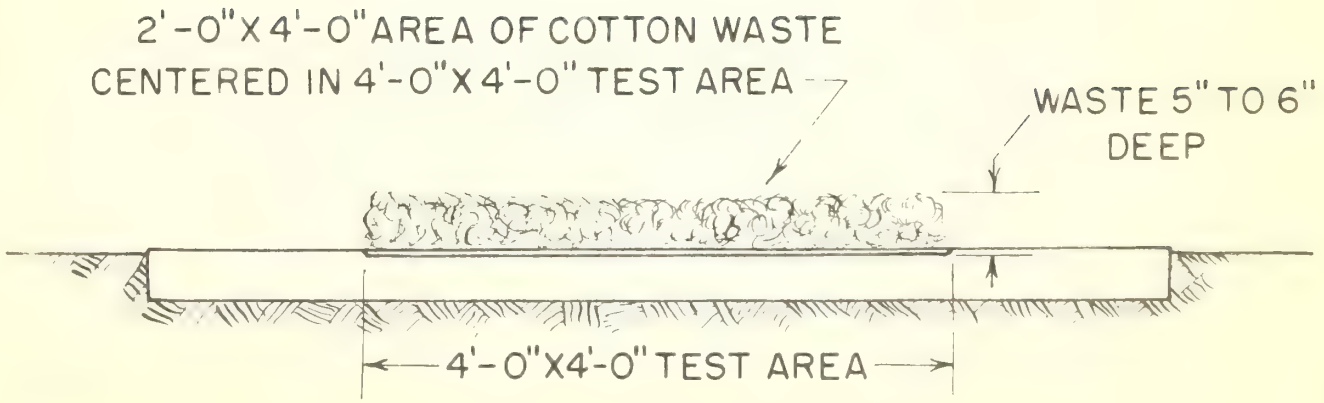
Type of Fire: Fuel saturated cotton waste

Test Apparatus: 8 lb cotton waste as shown

Fuel: 2 qt sprinkled over cotton waste

Preburn Time: 10 seconds

Method of Attack: Begin application at center of windward long edge



Fire Test No: 3 (CG-MMT-MBFT-III)

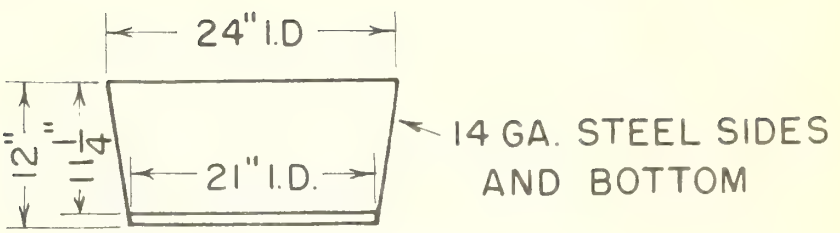
Type of Fire: Two-foot (nominal) tub

Test Apparatus: Tub as shown. Water to bring level to $10\frac{1}{2}$ in. below top of tub

Fuel: 2 qt poured on water

Preburn Time: 20 seconds

Method of Attack: Begin application to windward of tub, against opposite side wall.



Fire Test No: 4 (CG-MMI-MBFT-IV)

Type of Fire: Running, vertical and horizontal

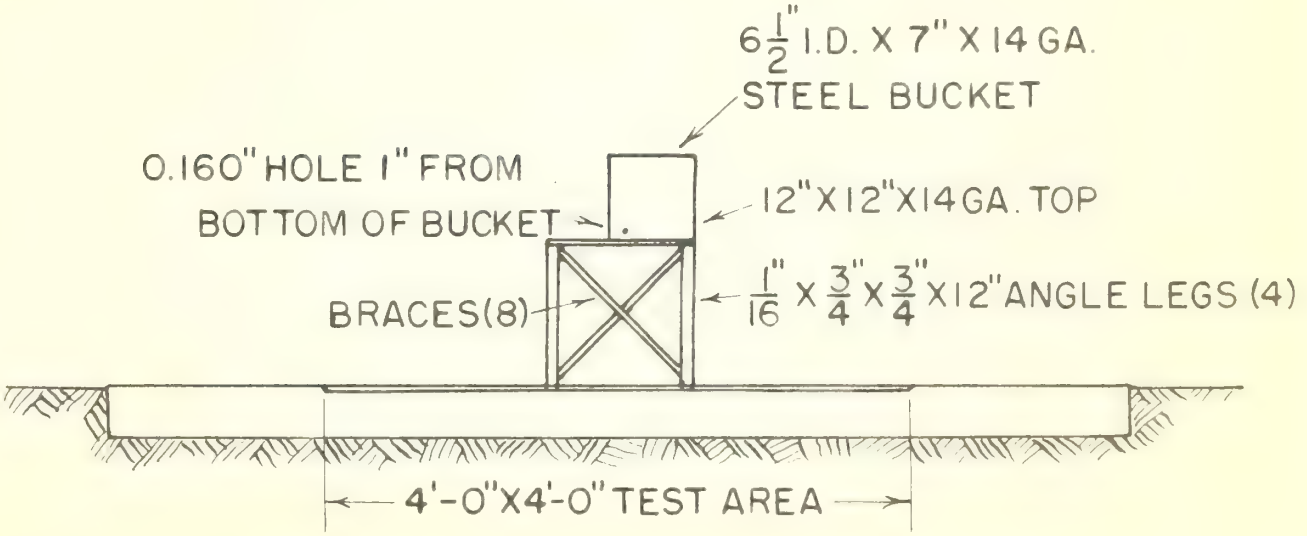
Test Apparatus: 1-gal covered bucket, set on metal stand, bucket flush with sides of stand in downwind corner, hole to direct stream upwind.

Fuel: 3 qt poured in bucket

Flow time: 10 seconds

Preburn time: 20 seconds

Method of Attack: Begin application to windward of spill



Fire Test No: 5 (CG-MMT-MBFT-IX)

Type of Fire: Flowing, vertical surface

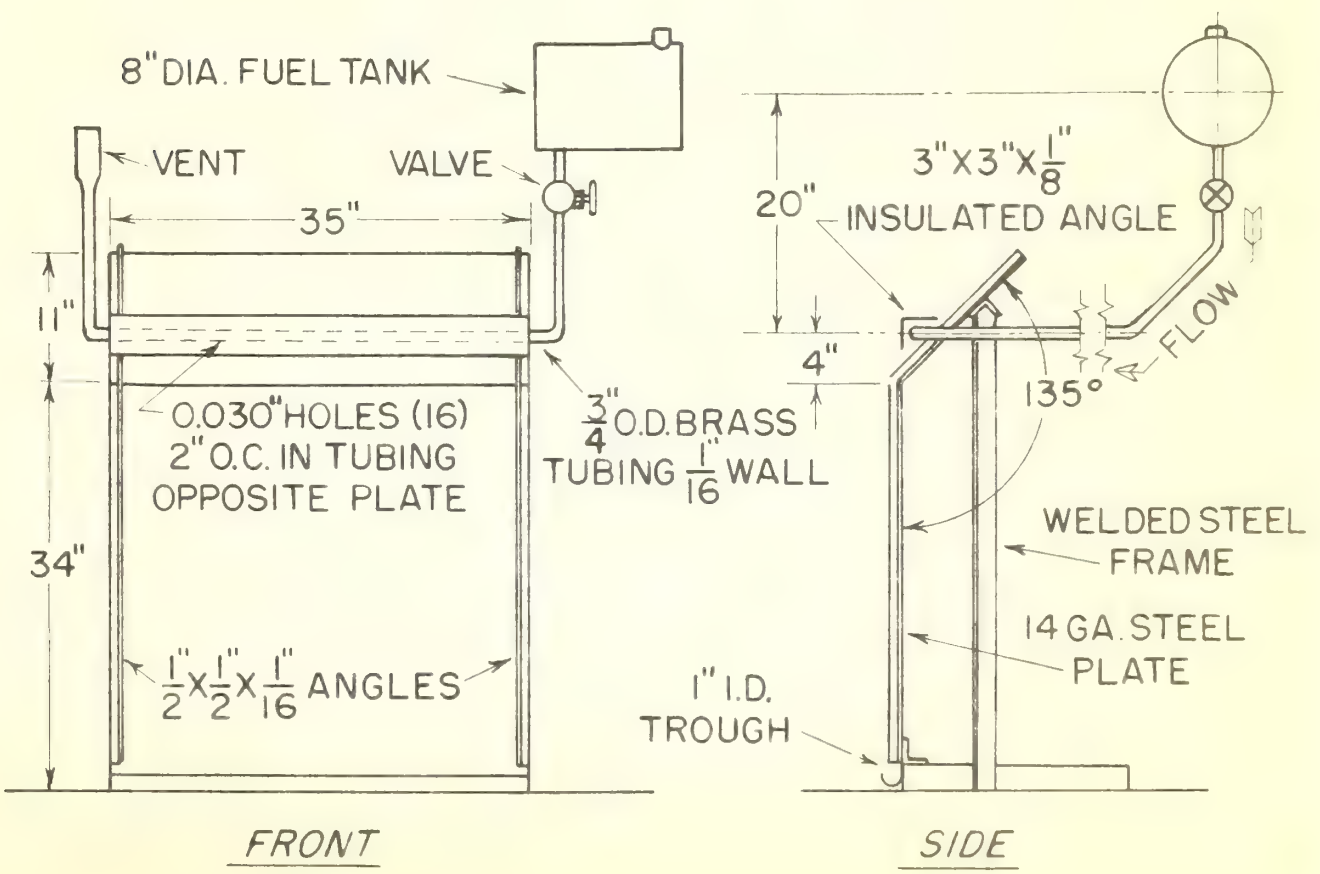
Test Apparatus: Shown in sketch

Fuel: 1 gal ethyl alcohol (denatured)

Flow Time: 10 seconds

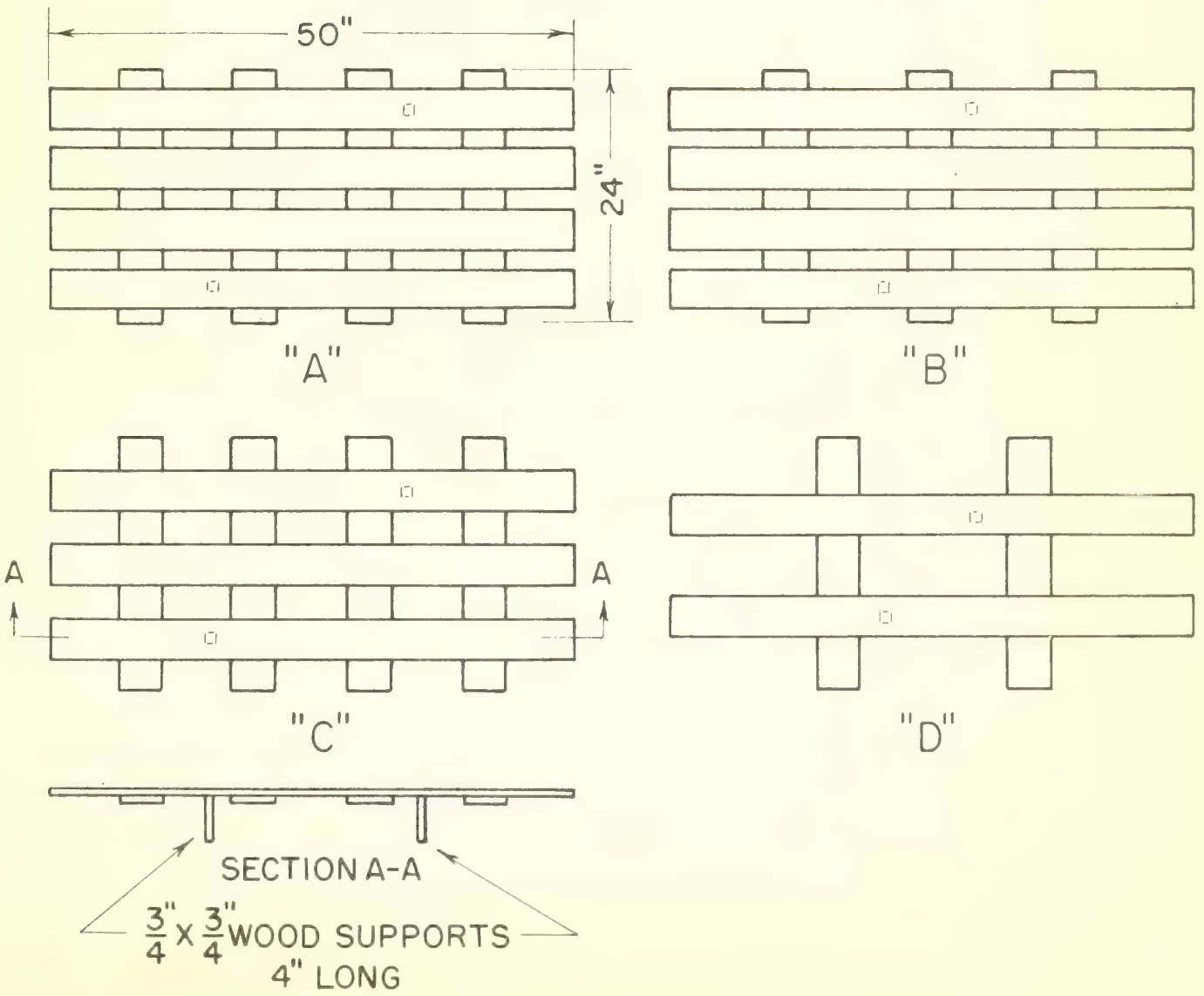
Preburn Time: 20 seconds

Method of Attack: Apparatus facing upwind, operator to windward



Wood Floor Gratings

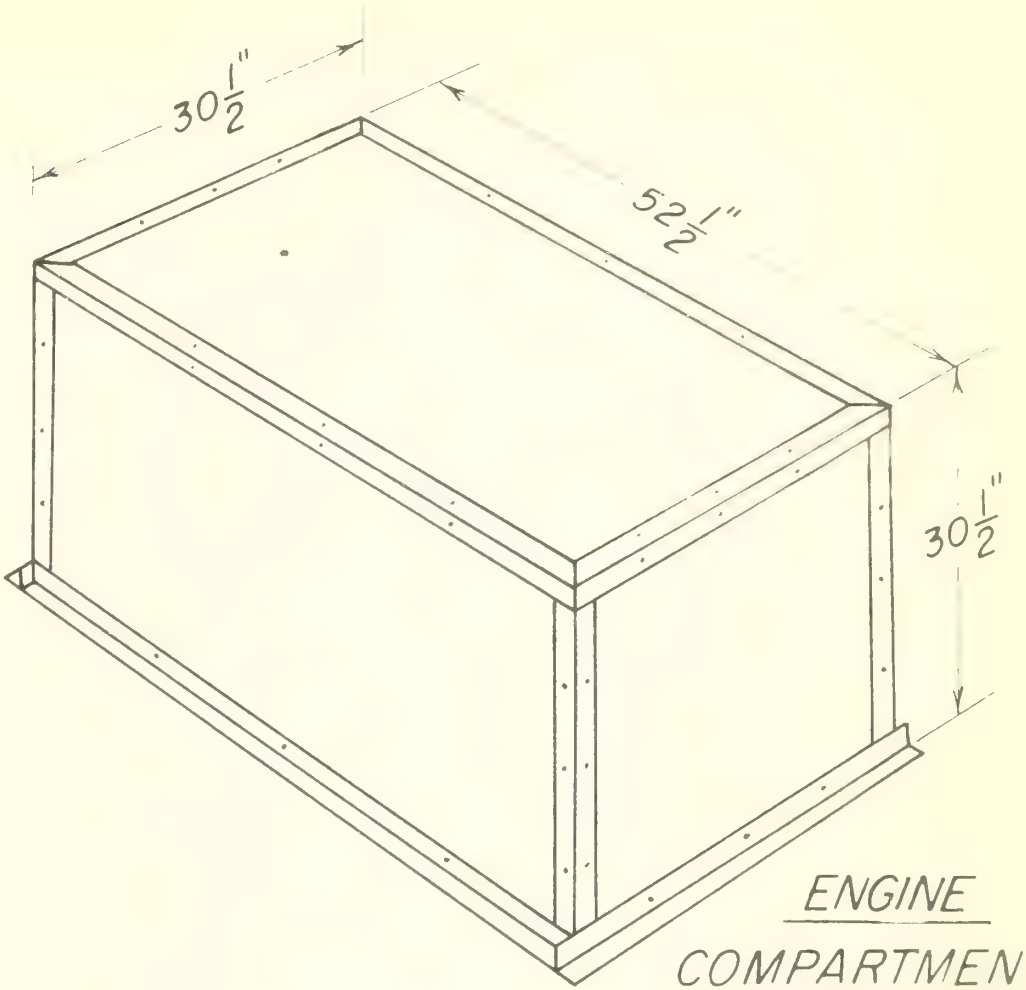
Gratings are constructed of Ponderosa Pine, No. 2 common, nominal 1-in. by 4-in. mill lumber (dressed dimensions 25/32 in. by 3 5/8 in.).



Engine Compartment and "Engine"

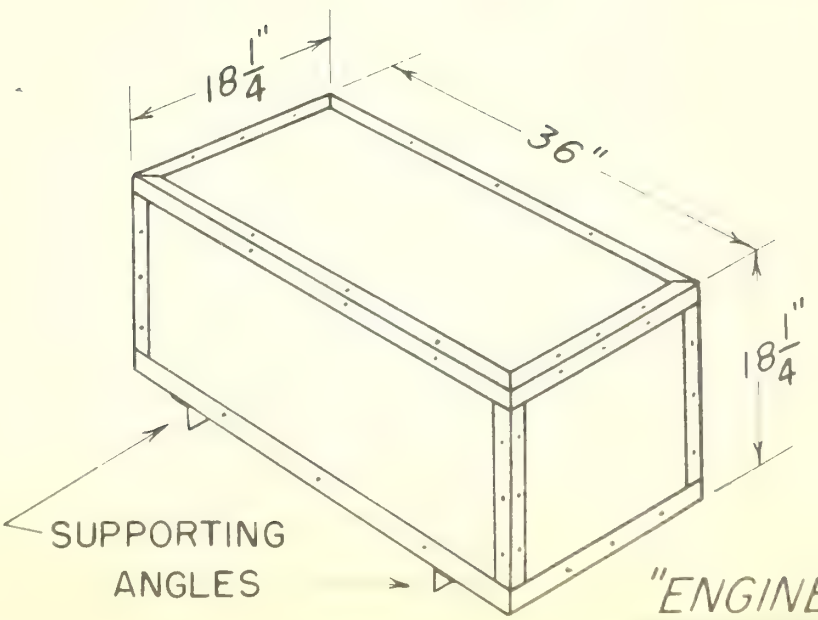
Both units made from 2-in. by 2-in. by 1/8-in. angle and 14 ga steel plate fastened with 1/4-in. bolts

Engine compartment made with bottom open, long sides covered, top and end plates removable.



ENGINE COMPARTMENT

"Engine" covered on all sides.



"ENGINE"

Fire Test No: 6 (CG-MMT-MBFT-V)

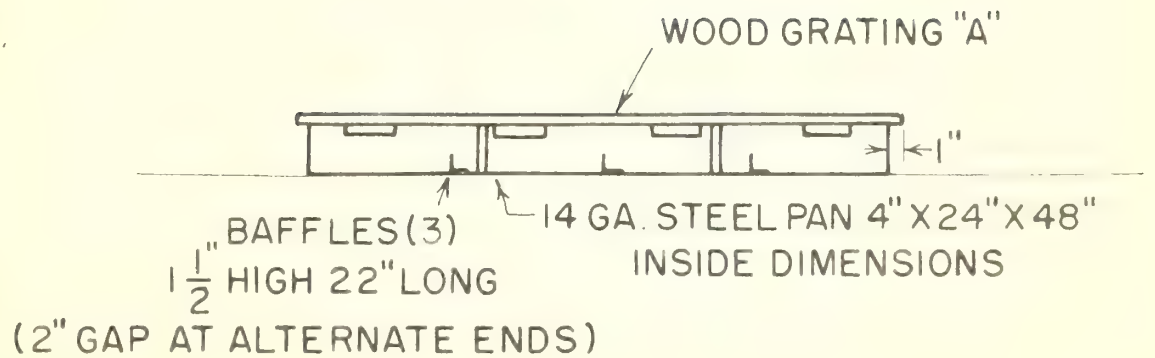
Type of Fire: Bilge

Test Apparatus: Shown in sketch. 1-in. depth water in pan.

Fuel: 1 gal on water in pan

Preburn Time: 60 seconds

Method of Attack: Begin application at center of windward long edge.



Fire Test No: 7

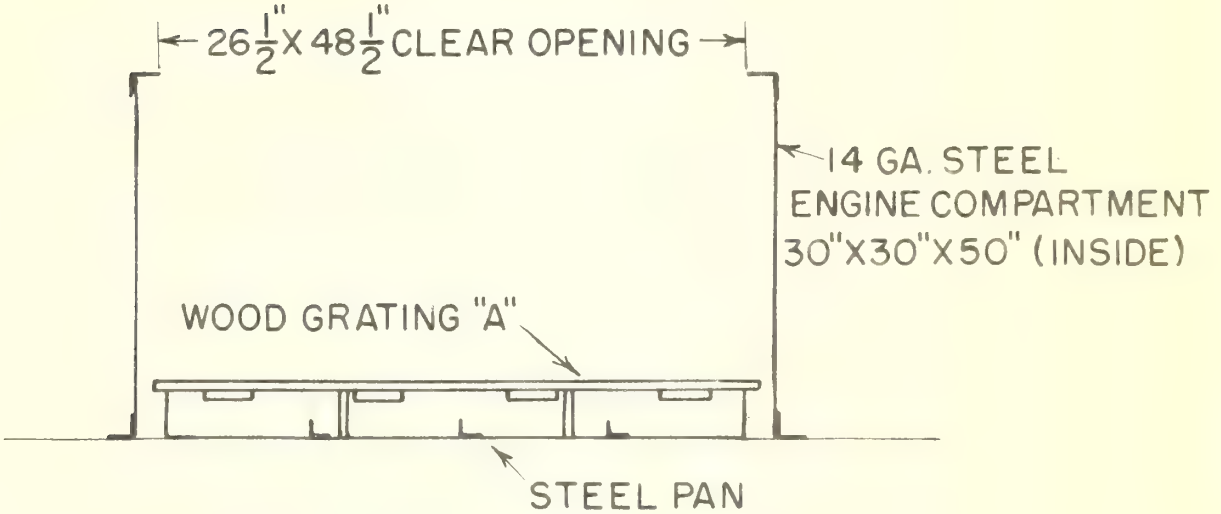
Type of Fire: Compartment (empty)

Test Apparatus: As shown; 1-in. water in pan

Fuel: 1 gal on water

Preburn Time: 60 seconds

Method of Attack: Through open top, at operator's discretion



Fire Test No: 8 (CG-MMT-MBFT-VII)

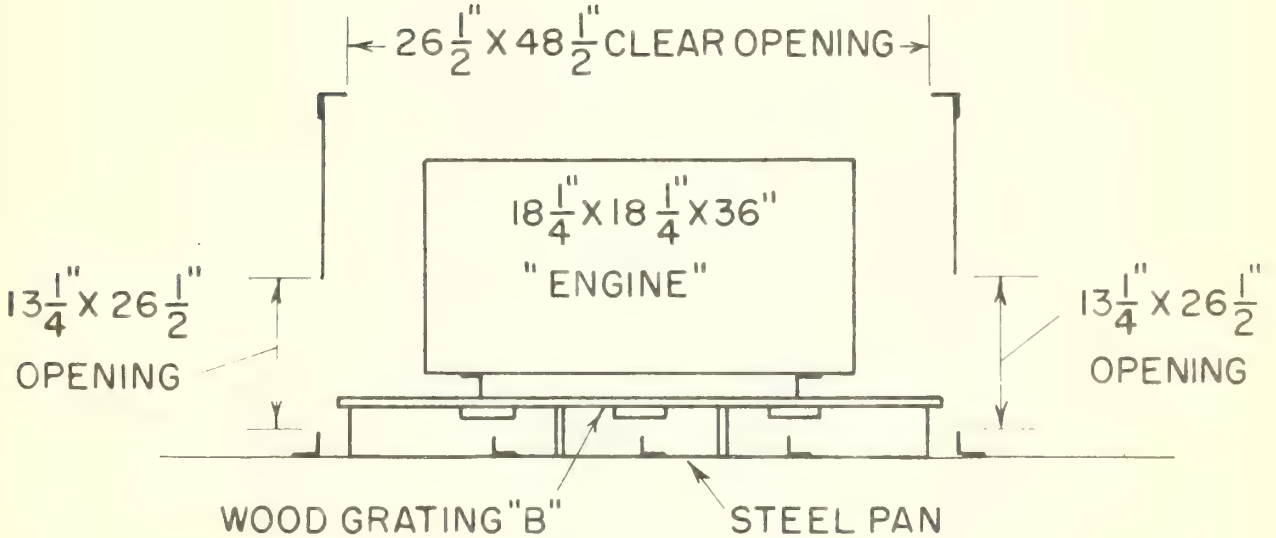
Type of Fire: Engine Compartment

Test Apparatus: Shown in sketch; 1-in. water in pan

Fuel: 1 gal on water

Preburn Time: 60 seconds

Method of Attack: At operator's discretion



Fire Test No: 9

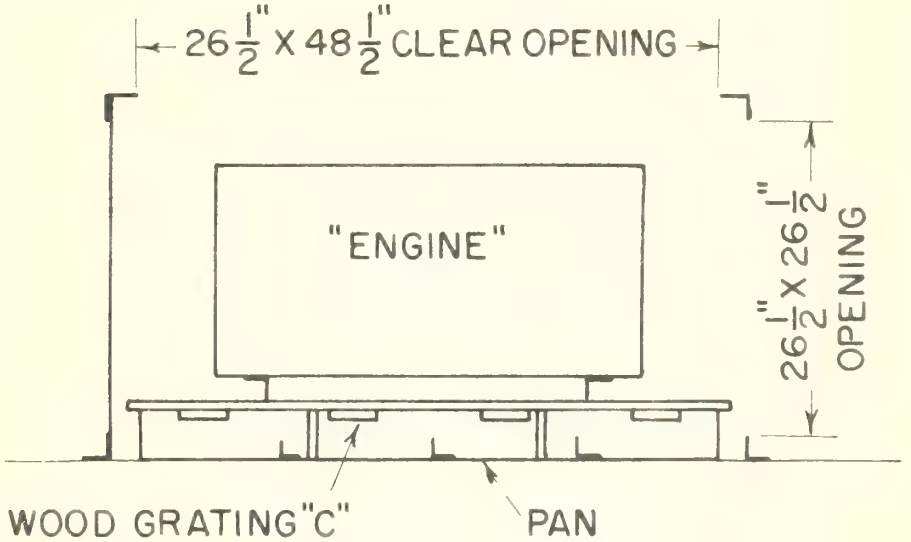
Type of Fire: Engine Compartment

Test Apparatus: Shown in sketch; 1-in. water in pan

Fuel: 1 gal on water

Preburn Time: 60 seconds

Method of Attack: At operator's discretion



Fire Test No: 10 (CG-MMT-MBFT-VI)

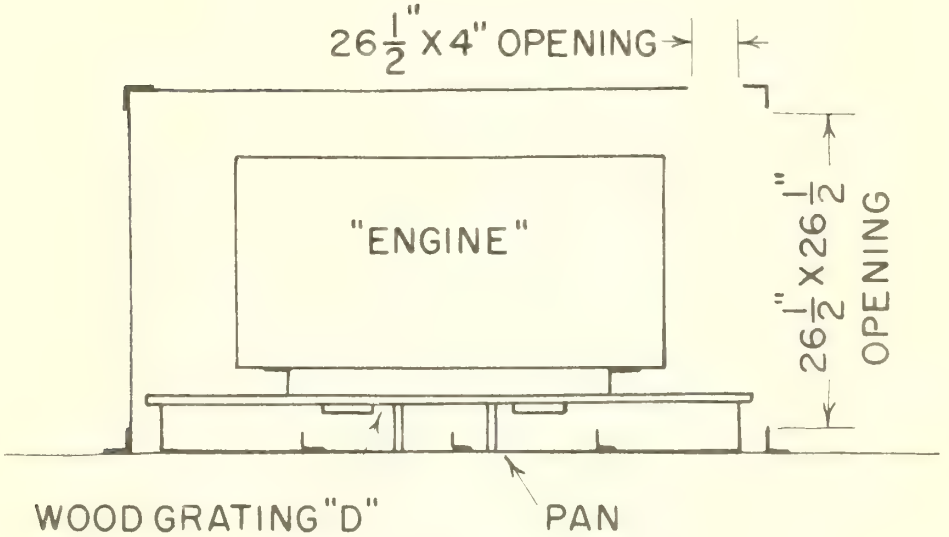
Type of Fire: Engine Compartment

Test Apparatus: Shown in sketch; 1-in. water in pan

Fuel: 1-gal on water

Preburn Time: 60 seconds

Method of Attack: Application through open end; at operator's discretion



APPENDIX C

Motorboat Fire Test Data

Fire No.	Date Time
Extinguisher No.	Extg type size
Manufacturer	Type of Charge Gas
Extg. Total Wt	Charge wt
Extg. Temp	Charge Pressure
WEATHER: sunny cloudy overcase rain in/hr	Test Area Shaded? yes no partly
	Velocity rev/min
Atm, Temperature	mile/hr
Wind Direction (to apparatus)	Wet Bulb
Humidity	Temp of Fuel, water
Fuel	Flow Time
Delay to ignition	Area of Fire Spread
Preburn	
Time Fire Out	Method of Attack
Time Extg Used	Initial Position
Final Wt	Target
Final Pressure	Procedure
Agent Expended	Final Position
Wood initial wt	Operator Recorder
Wood final wt	
Rating: -3,-2,-1;+1,+2,+3	
REMARKS:	Units: lb,sec,°F,psi

APPENDIX C

Motorboat Fire Test Data

Fire No.	Date	Time
Extinguisher No.	Extg type size	
Manufacturer	Type of Charge	Cap
Extg. Total Wt	Charge Wt	
Extg. Temp	Charge Pressure	
WEATHER:		
Rain in/hr sunny cloudy overcast	Test Area Bleached? Yes no partly	
Atm. Temperature	Velocity rev/min	
Wind Direction (to appraatus)	mile/hr	
Humidity	Wet Bulb	
Fuel	Temp of Fuel, water	
Delay to Ignition	Flow Time	
Pressure	Area of Fire Spread	
Time Fire Out	Method of Attack	
Time Extg Used	Initial Position	
Final Wt	Target	
Final Pressure	Procedure	
Agent Expended	Final Position	
Good Initial Wt	Operator	Recorder
Good Final Wt		
Rating: -3,-2,-1,0,+1,+2,+3		
REMARKS:		

Units: lb,sec,%,psi